# Glen Canyon Dam
# Draft Environmental Impact Statement

*STATUS OF ALTERNATIVES*

**Prepared by EIS Team**
**for presentation to**
**Cooperating Agencies**

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**Phoenix, Arizona**

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## ALTERNATIVES IDENTIFIED FOR DETAILED ANALYSIS

| | STEADY FLOW | | | FLUCTUATING FLOW | | | |
|---|---|---|---|---|---|---|---|
| | Year-round | Seasonally Adjusted | Existing Monthly Volume | Low | Moderate | High | No Action (Existing Limits) |
| Minimum flow (cfs) | Yearly volume prorated | 7,000 Oct–Dec<br>11,000 Jan–Mar<br>20,000 Apr–Jun<br>7,000 Jul–Sep | 8,000 | 5,000 between 7:00 pm and 7:00 am<br>8,000 between 7:00 am and 7:00 pm | [1]5,000 | 3,000<br>5,000<br>8,000 depending upon monthly volume, firm load, and market conditions | 1,000 Labor Day–Easter<br>3,000 Easter–Labor Day |
| Allowable daily change in flow (cfs/day) | 2,000 between days | 2,000 between days | 2,000 between days | [2]5,000<br>6,000 or<br>8,000 | +/-45% of mean daily flow for the month NTE 12,000[2] | 15,000 through 22,000 | 30,500 Labor Day–Easter<br>28,500 Easter–Labor Day |
| Maximum releases (cfs)[3] | Yearly volume prorated | Four seasonal volumes prorated | Monthly volumes prorated | 20,000 | Based on monthly volumes and allowed daily changes | 31,500 | 31,500<br>Full powerplant capacity studied as a subalternative 33,200 |
| Allowable ramping (cfs/hour) | None[4] | None[4] | None[4] | 2,500 up<br>1,500 down | 4,000 up<br>2,500 down | Follow power load up and 5,000 or 4,000 down | Follow power load[5] |
| Flood frequency | | | | | | | |
| Research and monitoring | ← Applies to All Alternatives → | | | | | | |
| Other elements potentially applied to any alternative | Sand pumping<br>Beach protection<br>Beach/habitat building flows<br>Reduced flood frequency<br>Modifying the spillway gate<br>Lowering the target pool elevation<br>Multilevel intake structures<br>Power system adjustment | | | | | | None |

[1] In high volume release months, the allowable daily change would require higher minimum flows. For example, the minimum would be 14,000 cfs for a monthly release volume of 1.2 maf.

[2] Daily fluctuation limit of 5,000 cfs for monthly release volumes less than 600,000 acre-ft; 6,000 cfs for monthly release volumes of 600,000 to 800,000 acre-feet; and 8,000 cfs for monthly volumes over 800,000 acre-ft.

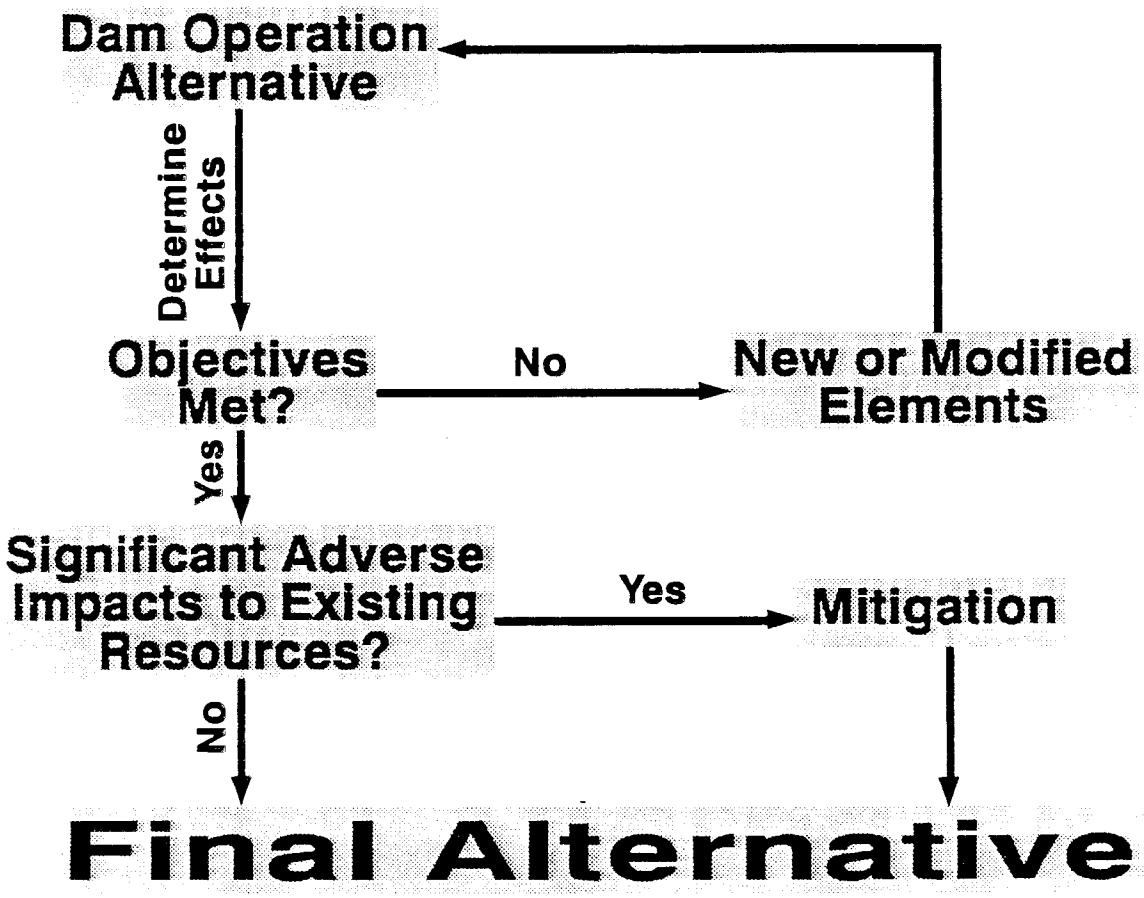
[3] Maximums represent normal or routine limits and could be exceeded during high water years to avoid releases above powerplant capacity. Some operations would have the following maximum flows that would vary with different monthly volumes. For example:

| | Low Water Year (8.23 maf) | High Water Year (16 maf) |
|---|---|---|
| Year-round | 12,000 cfs | 22,000 cfs |
| Seasonally adjusted | 20,000 cfs | 31,500 cfs |
| | Low Month (550,000 af) | High Month (1.2 maf) |
| Existing monthly volumes | 9,000 cfs | 20,000 cfs |
| Low fluctuations | 13,000 cfs | 20,000 cfs |
| Moderate fluctuations | 15,000 cfs | 26,000 cfs |
| High fluctuations | 20,000 cfs | 31,500 cfs |

[4] Adjustments would allow +/- 1,000 cfs for power system load changes.

[5] Approximately 8,000 cfs/hour maximum.

# ALTERNATIVE FORMULATION

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**Elements Potentially Added to Any Alternative**

- Sand pumping
- Beach protection
- Beach/habitat building flows
- Reduced flood frequency
- Multilevel intake structure
- Power system adjustments

## YEAR-ROUND STEADY FLOW ALTERNATIVE

- **Objective.** The Year-Round Steady Flow Alternative was developed in response to scoping comments calling for complete elimination of fluctuating flows. This alternative would release water from Glen Canyon Dam at a year-round steady rate, thus eliminating daily river fluctuations and minimizing peak discharges in order to preserve existing beaches and sediment-dependent resources.

- **Range of Fluctuating Flows.** Flows would be held steady throughout the year, subject to forecast adjustments. In the event changes were required between months to respond to forecast changes, flows would remain steady within each month.

- **Maximum Flow.** Maximum flow rates would be determined by the annual volume of water to be released, and could require use of the outlet works and spillways during high water years when Lake Powell is full. Up to 33,200 cfs could be discharged through the powerplant. Flows greater than this capacity would be discharged through the outlet works first and subsequently through the spillways, as required. Releases in excess of 31,500 cfs—the current limitation on releases—have historically (1966-89) occurred only in the months of May through August, about 9, 12, 7, and 2 percent of the time in those months.

- **Minimum Flow.** The minimum flow would correspond to the minimum annual release volume of 8.23 million acre-feet, which is about 11,400 cfs. The following figure compares estimated release patterns from Glen Canyon Dam for this alternative under conditions experienced in water year 1989 with historical operations.

- **Annual Volume.** The scheduled annual release volume would be determined using existing practices, based on considerations for maintaining conservation storage, avoiding spills, and balancing storage between Lakes Powell and Mead. Constant annual releases would be 11,400; 16,600; and 22,100 cfs for annual volumes of 8.23; 12.0; and 16.0 million acre-feet, respectively. Adjustments in releases could be required throughout the year in response to changes in forecasted inflow to Lake Powell.

- **Monthly Volume.** The monthly volume would be the annual volume divided by 12, except under circumstances where adjustments would be required in responding to forecast changes.

- **Daily Volume.** The daily volume would be the monthly volume divided by the number of days in the month.

- **Forecast Adjustments.** The volume of water to be released during the remainder of the year would be recomputed monthly based on updated streamflow forecast information (as it is under existing practices), and the constant rate of release would be adjusted accordingly. The ability to maintain a constant rate of release for the entire year would be dependent on the accuracy of streamflow forecasts and the amount of space remaining in Lake Powell.

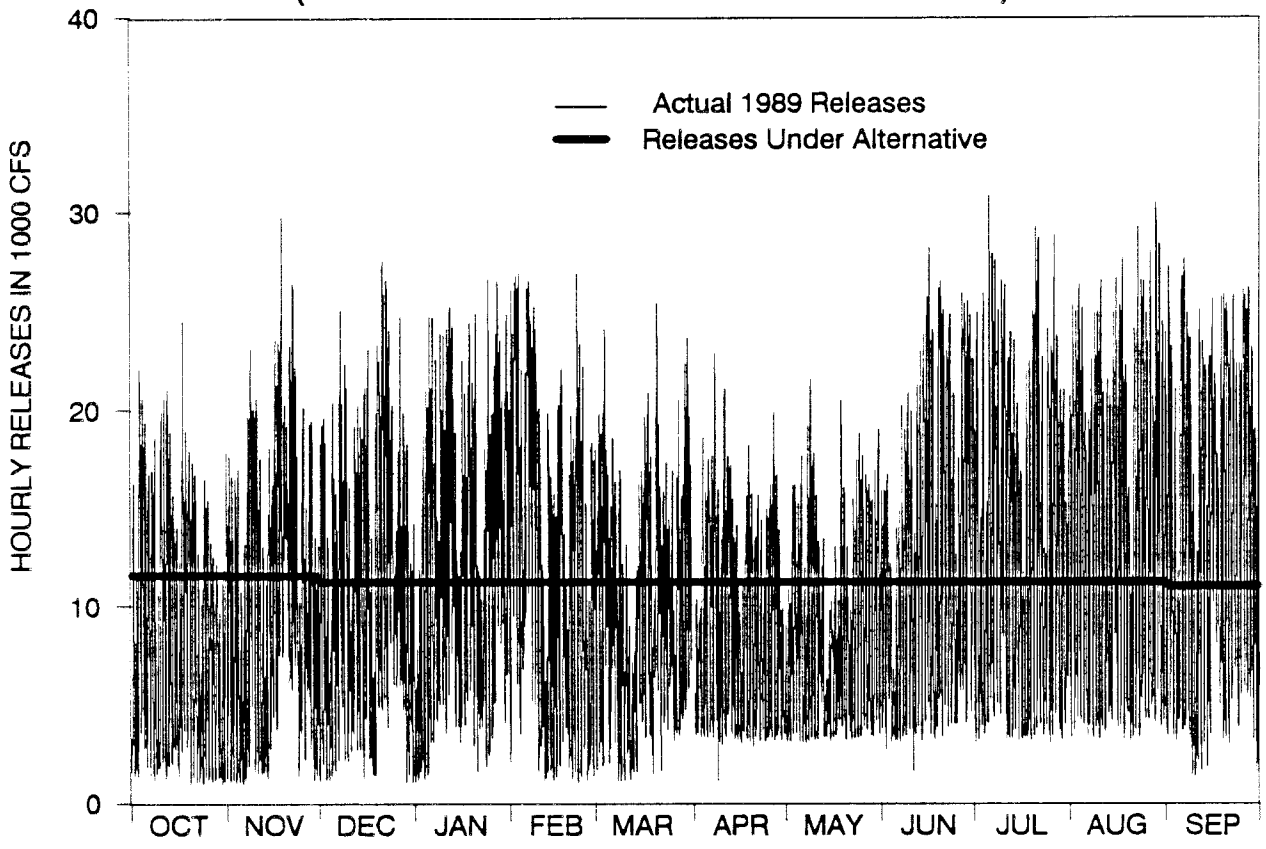
- **Avoidance of Spills.** For years in which Lake Powell is expected to fill, steady releases would be scheduled to avoid spills and meet existing reservoir target elevations. Operational flexibility necessary to avoid spills and maintain conservation storage would be the same as current operations.

- **Ramping Rate.** The maximum ramping rate in adjusting flows between months because of forecast changes would be 2,000 cfs per day.

- **Power Considerations.** Power operations would be driven almost entirely by constant water release requirements, except for electrical system emergencies. Daily variations of ±1,000 cfs/day (approximately 42 MW) would allow some minor flexibility at the dam to be used primarily for regulation.

# Hourly Releases -- Year-Round Steady Flow Alt.

**(1989 Conditions – 8.2 maf annual release)**



## SEASONALLY ADJUSTED STEADY FLOW ALTERNATIVE

- **Objective.** The Seasonally Adjusted Steady Flow Alternative was developed in response to scoping comments requesting a flow regime to address the varying seasonal needs of downstream resources. This refinement of the Year-round Steady Flow Alternative would release water from Glen Canyon Dam at a constant rate within each of four seasons, in order to preserve the altered ecosystem that currently exists downstream of the dam.

- **Seasons.** The seasons would be fall (October through December), winter (January through March), spring (April through June), and summer (July through September).

- **Range of Fluctuating Flows.** Flows would be held steady throughout each season, subject to forecast adjustments. In the event changes were required between months to respond to forecast changes, flows would remain steady within each month.

- **Maximum Flow.** Maximum steady releases would be determined by the seasonal volume of water to be released. Adjustments in releases required by forecast changes would be distributed throughout subsequent seasons. Use of the powerplant, outlet works, and spillway may be required during high water years when Lake Powell is full.

- **Minimum Flows.** The constant release for each respective season would be based on minimum flows of 7,000; 11,000; 20,000; and 7,000 cfs. Required release volumes greater than the minimums would be distributed proportionally among the remaining seasons. The following figure compares estimated release patterns from Glen Canyon Dam for this alternative under conditions experienced in water year 1989 with historical operations.

- **Annual Volume.** The scheduled annual release volume would be determined using existing practices, based on considerations for maintaining conservation storage, avoiding spills, and balancing storage between Lakes Powell and Mead.

- **Seasonal Volume.** Releases would be steady within each season, except under circumstances where adjustments would be required in response to forecast changes.

- **Daily Volume.** The daily volume would be the monthly volume divided by the number of days in the month.

- **Forecast Adjustments.** The volume of water to be released during the remainder of the year would be recomputed monthly based on updated streamflow forecast information (as it is under existing practices), and the rate of release for remaining seasons would be adjusted accordingly. The ability to maintain a constant rate of release for each season would be dependent on the accuracy of the streamflow forecasts and the amount of storage available in Lake Powell.

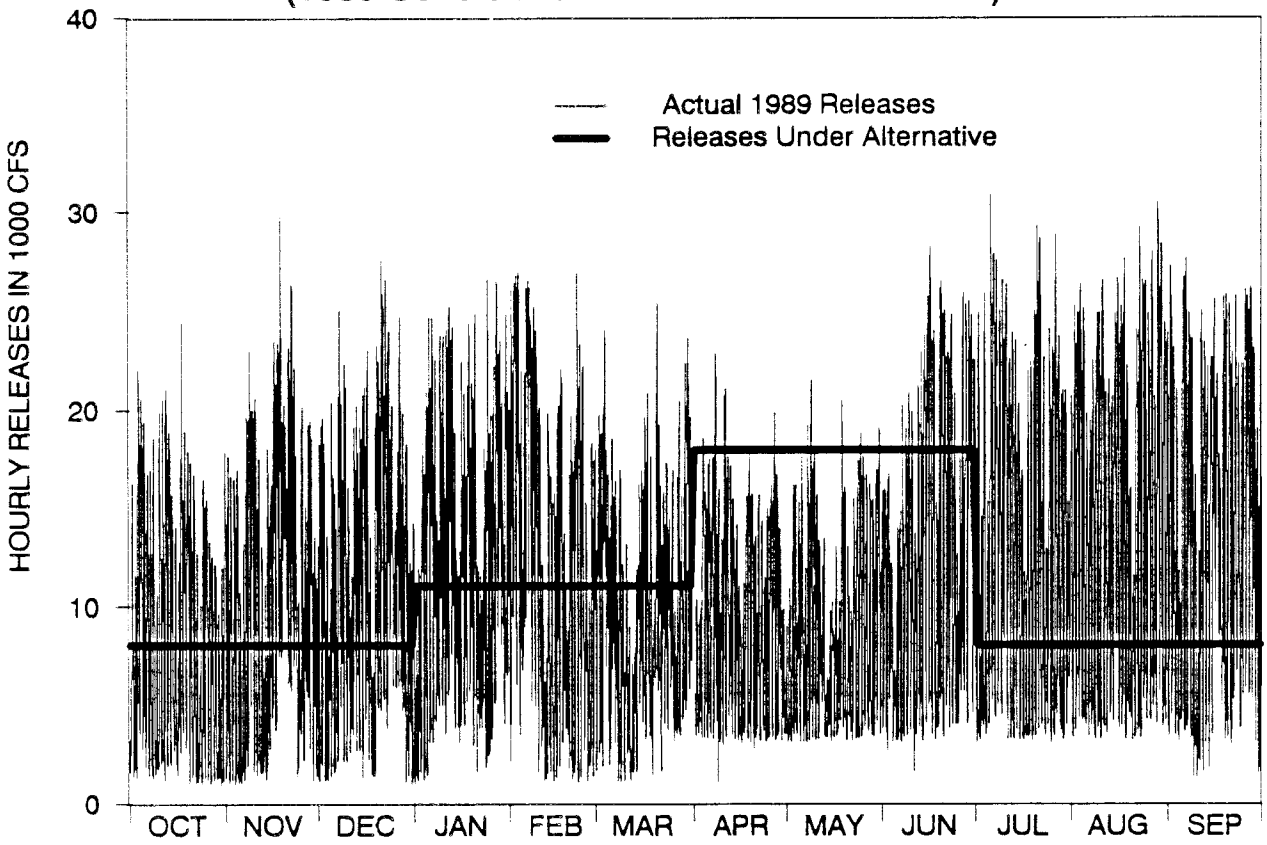
- **Avoidance of Spills.** For years in which Lake Powell is expected to fill, steady releases would be scheduled to avoid spills and meet existing reservoir target elevations. Operational flexibility necessary to avoid spills and maintain conservation storage would be the same as current operations.

- **Ramping Rate.** The maximum ramping rate in adjusting flows between months would be 2,000 cfs per day.

- **Power Considerations.** Power operations would be driven almost entirely by constant water release requirements, except for electrical system emergencies. Daily variations of ±1,000 cfs/day (approximately 42 MW) would allow some minor flexibility at the dam to be used primarily for regulation.

# Hourly Releases -- Seas-Adj. Steady Flow Alt.

**(1989 Conditions – 8.2 maf annual release)**



## EXISTING MONTHLY VOLUME STEADY FLOW ALTERNATIVE

- **Objective.** The Existing Monthly Volume Steady Flow Alternative was developed in an attempt to integrate the concepts of steady flow and current monthly water delivery schedules. This alternative would release water from Glen Canyon Dam at a constant rate within each month to maintain the operational flexibility necessary to avoid spills and maintain conservation storage while eliminating the possible negative effects of daily fluctuating flows on downstream resources.

- **Range of Fluctuating Flows.** Flows would be held steady throughout each month.

- **Maximum Flow.** Maximum steady releases would be determined by the monthly volume of water to be released. Adjustments in releases required by forecast changes would be distributed throughout subsequent months. Use of the powerplant, outlet works, and spillway may be required during high water years when Lake Powell is full.

- **Minimum Flow.** The minimum flow would be 8,000 cfs, which is equivalent to about 480,000 acre-feet per month. In critical water years, the monthly volume could be somewhat less, thus necessitating a corresponding drop in the minimum rate of release. The following figure compares estimated release patterns from Glen Canyon Dam for this alternative under conditions experienced in water year 1989 with historical operations.

- **Annual and Monthly Volumes.** The scheduled monthly and annual release volumes would be determined using existing practices, based on considerations for maintaining conservation storage, avoiding spills, balancing storage between Lakes Powell and Mead, and power needs. Fall and winter monthly release volumes have been close to 500,000 acre-feet about 50 percent of the time for the period 1963 through 1989.

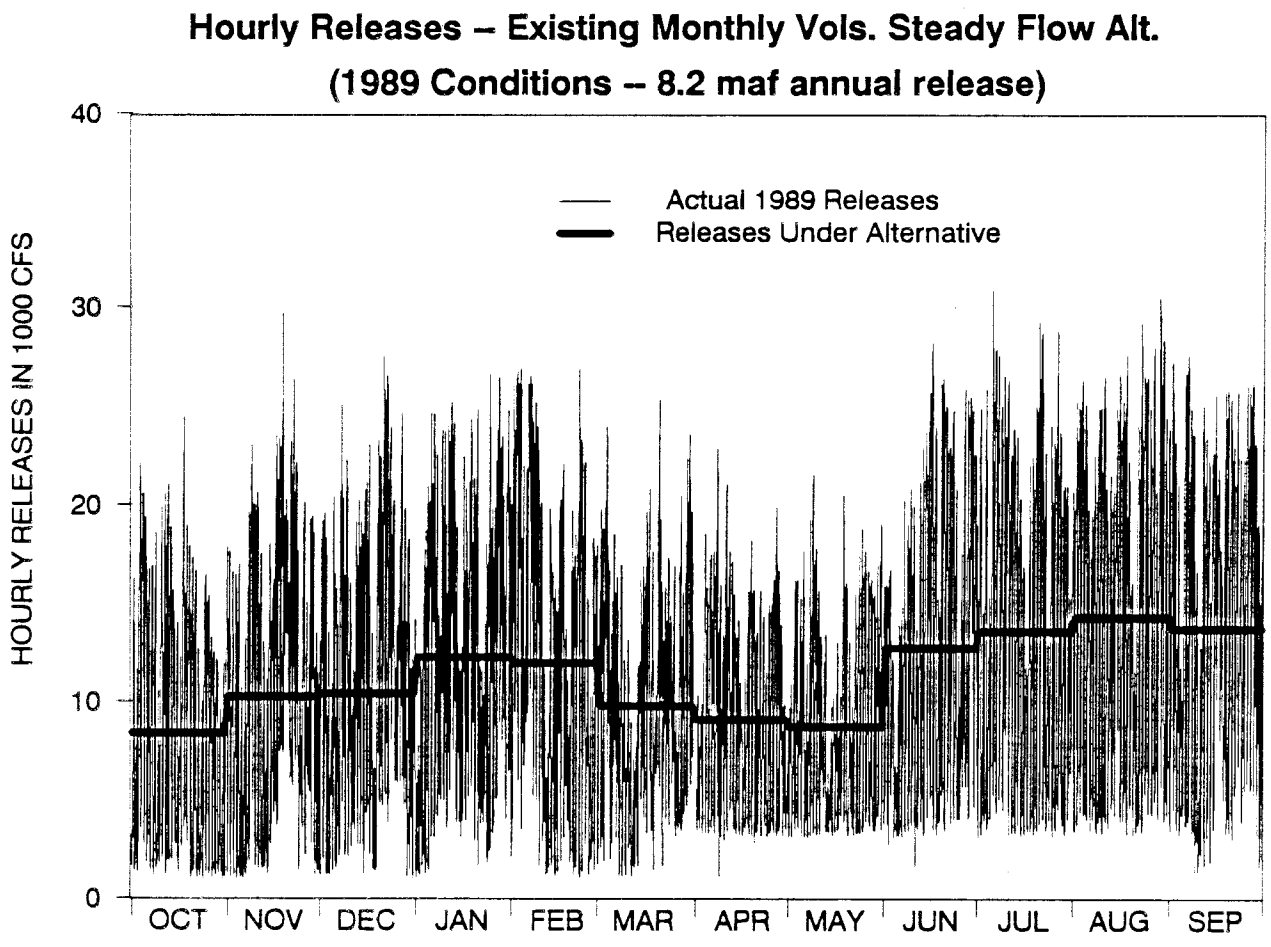
- **Daily Volume.** The daily volume would be the monthly volume divided by the number of days in the month.

- **Forecast Adjustments.** The volume of water to be released during the remainder of the year would be recomputed monthly based on updated streamflow forecast information (as it is under existing practices), and the rate of release for remaining months would be adjusted accordingly.

- **Avoidance of Spills.** Operational flexibility necessary to avoid spills and maintain conservation storage would be the same as current operations.

- **Ramping Rate.** The maximum ramping rate in adjusting flows between months would be 2,000 cfs per day.

- **Power Considerations.** Power operations would be driven almost entirely by constant water release requirements, except for electrical system emergencies. Daily variations of ±1,000 cfs/day (approximately 42 MW) would allow some minor flexibility at the dam to be used primarily for regulation.


Hourly Releases -- Existing Monthly Vols. Steady Flow Alt.
(1989 Conditions -- 8.2 maf annual release)
HOURLY RELEASES IN 1000 CFS
40
30
20
10
0
Actual 1989 Releases
Releases Under Alternative
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP

## LOW FLUCTUATING FLOW ALTERNATIVE

- **Objective.** The Low Fluctuating Flow Alternative was developed to permit fluctuating flows well below existing levels. This alternative would release water from Glen Canyon Dam in a manner that would significantly decrease the daily magnitude of fluctuating flows and ramping rates, in order to reduce the possible adverse effects of current powerplant operations on downstream beaches, sediment-dependent resources, and aquatic resources.

- **Range of Fluctuating Flows.** Daily fluctuations would be limited to 5,000, 6,000, or 8,000 cfs depending on monthly release volumes.

- **Maximum Flow.** The maximum fluctuating flow would be 20,000 cfs; any releases greater than 20,000 cfs would be steady. The following figure compares estimated operations under this alternative with current operations for a day in July 1989.

- **Minimum Flow.** Minimum flows would be 5,000 cfs between 7:00 pm and 7:00 am and 8,000 cfs between 7:00 am and 7:00 pm. The duration of 5,000 cfs flows would be limited to 6 hours.

- **Annual and Monthly Volumes.** The scheduled annual and monthly release volumes would be determined using existing practices based on considerations for maintaining conservation storage, avoiding spills, balancing storage between Lakes Powell and Mead, and power needs.

- **Daily Volumes.** The mean daily release volume would be determined principally from the monthly volume. The daily release pattern could tend to be low and steady in some instances (e.g. the powerplant could be baseloaded on Sunday between 5,000 and 8,000 cfs).

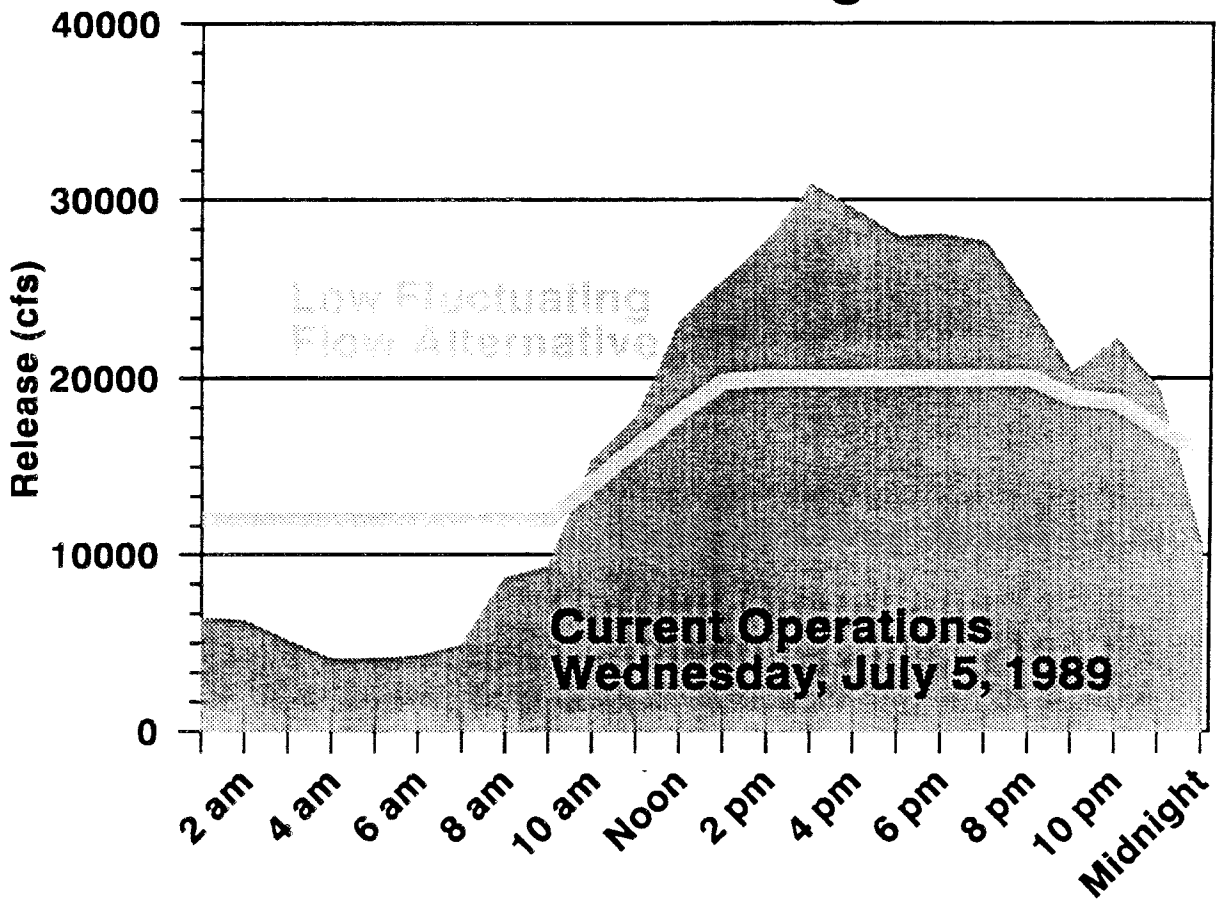
- **Forecast Adjustments.** The volume of water to be released during the remainder of the year would be recomputed monthly based on updated streamflow forecast information (as it is under existing practices), and the rate of release for remaining months would be adjusted accordingly.

- **Avoidance of Spills.** Operational flexibility necessary to avoid spills and maintain conservation storage would <u>not</u> be affected.

- **Ramping Rate.** The ramping rate would be limited to 2,500 cfs per hour for increasing flows and 1,500 cfs per hour for decreasing flows.

- **Power Considerations.** Power operations would be dependent on monthly water release volumes. Generally, power operations would optimize the water allocation to maximize the ability to generate to meet firm load and to allow greater purchases during off-peak periods, given the release restrictions.

# A day in July under the LOW FLUCTUATING FLOW ALTERNATIVE might look like...



## MODERATE FLUCTUATING FLOW ALTERNATIVE

- **Objective.** The Moderate Fluctuating Flow Alternative was developed to permit fluctuating flows below existing levels. This alternative would release water from Glen Canyon Dam in a manner that would reduce the daily magnitude of fluctuating flows and ramping rates, in order to reduce the possible adverse effects of current powerplant operations on downstream beaches, sediment-dependent resources, aquatic resources.

- **Range of Fluctuating Flows.** Daily fluctuations would be limited to ±45 percent of the mean monthly flow but not to exceed 12,000 cfs. The allowable daily fluctuations would be about 7,500; 12,000; and 12,000 cfs, corresponding to monthly volumes of 500,000; 1,000,000; and 1,500,000 acre-feet; respectively.

- **Maximum Flow.** The maximum fluctuating flow would be limited to 31,500 cfs. Any releases greater than 31,500 cfs would be steady. The following figure compares estimated operations under this alternative with current operations for a day in July 1989.

- **Minimum Flow.** Minimum flows would be 5,000 cfs for all months.

- **Annual and Monthly Volumes.** The scheduled annual and monthly release volumes would be determined using existing practices, based on considerations for maintaining conservation storage, avoiding spills, and balancing storage between Lakes Powell and Mead, and power needs.

- **Daily Volumes.** The mean daily release volume would be determined principally from the mean monthly volume. The actual daily release volume could vary between the limits of fluctuating flow for that month. The daily release pattern could tend to be steady in extreme applications of this alternative (e.g. if the mean daily flow for a given month were 15,000 cfs, the powerplant could be baseloaded on Sunday at 9,000 cfs).

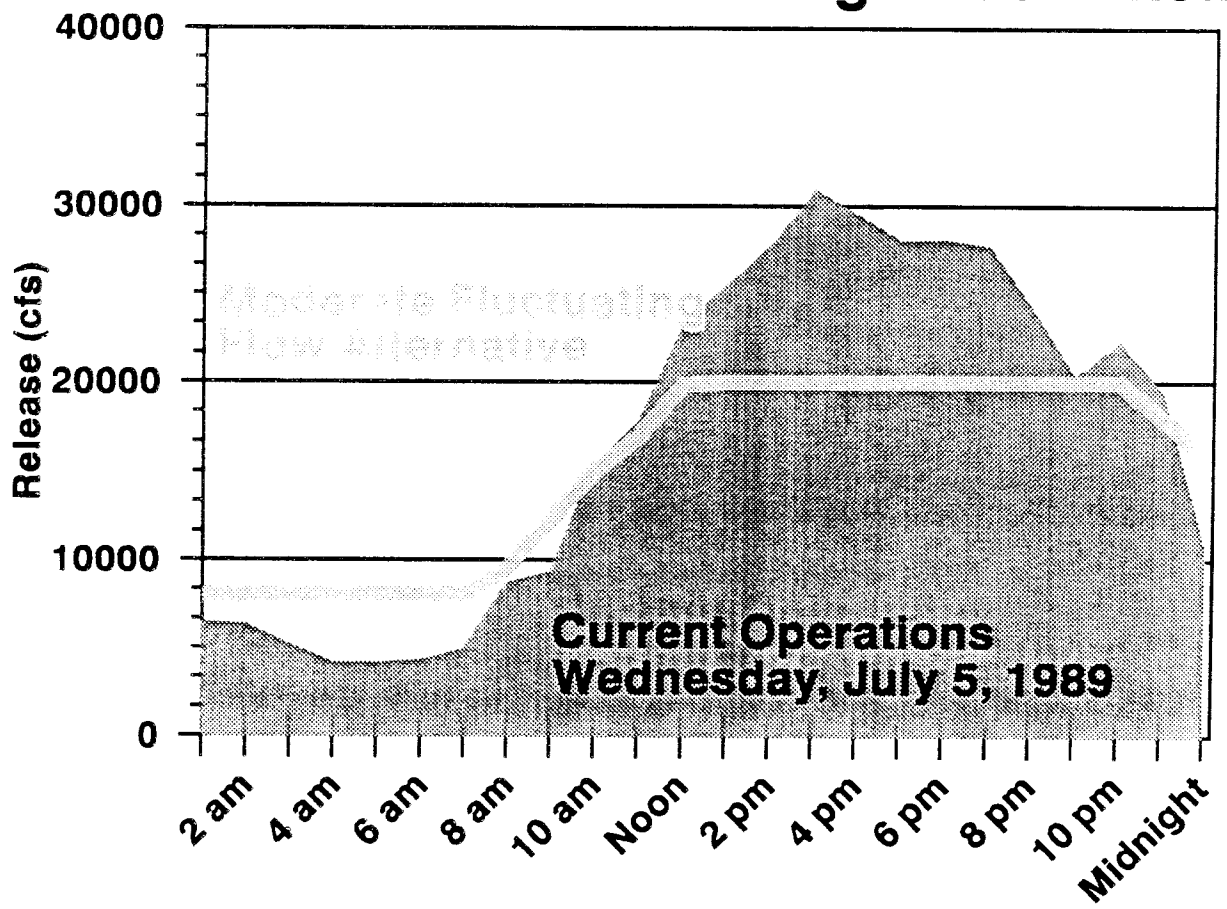
- **Forecast Adjustments.** The volume of water to be released during the remainder of the year would be recomputed monthly based on updated streamflow forecast information (as it is under existing practices), and the rate of release for remaining months would be adjusted accordingly.

- **Avoidance of Spills.** Operational flexibility necessary to avoid spills and maintain conservation storage would <u>not</u> be affected.

- **Ramping Rate.** The ramping rate would be limited to 4,000 cfs/hr for increasing flows and 2,500 cfs/hr for decreasing flows.

- **Power Considerations.** Power operations are dependent on monthly water release volumes. Generally, power operations would optimize the water allocation to maximize the ability to generate to meet firm load and to allow greater purchases during off-peak periods, given the release restrictions.

# A day in July under the MODERATE FLUCTUATING FLOW ALTERNATIVE might look like...



## HIGH FLUCTUATING FLOW ALTERNATIVE

- **Objective.** The High Fluctuating Flow Alternative was developed to maintain the integrity of Glen Canyon Dam as a flexible hydropower resource while meeting critical needs of other resources. Rather than imposing absolute restrictions on Glen Canyon Dam, this alternative relates releases to hydrology, power system flexibility, and certain resource needs.

- **Range of Fluctuating Flows.** Daily fluctuations would be limited to 15,000, 18,000, 20,000, 21,000, or 22,000 cfs depending on the monthly release volume.

- **Maximum Flow.** The maximum fluctuating flow would be limited to 31,500 cfs. Any releases greater than 31,500 cfs would be steady. The following figure compares estimated operations under this alternative with current operations for a day in July 1989.

- **Minimum Flow.** Minimum flows would be 3,000, 5,000, or 8,000 cfs depending on monthly volume, firm load, and market conditions.

- **Annual and Monthly Volumes.** The scheduled annual and monthly release volumes would be determined using existing practices, based on considerations for maintaining conservation storage, avoiding spills, and balancing storage between Lakes Powell and Mead, and power needs.

- **Daily Volumes.** The mean daily release volume would be determined principally from the mean monthly volume. The daily release pattern could tend to be low and steady in some instances (e.g., the powerplant could be baseloaded on Sunday at 3,000 cfs).

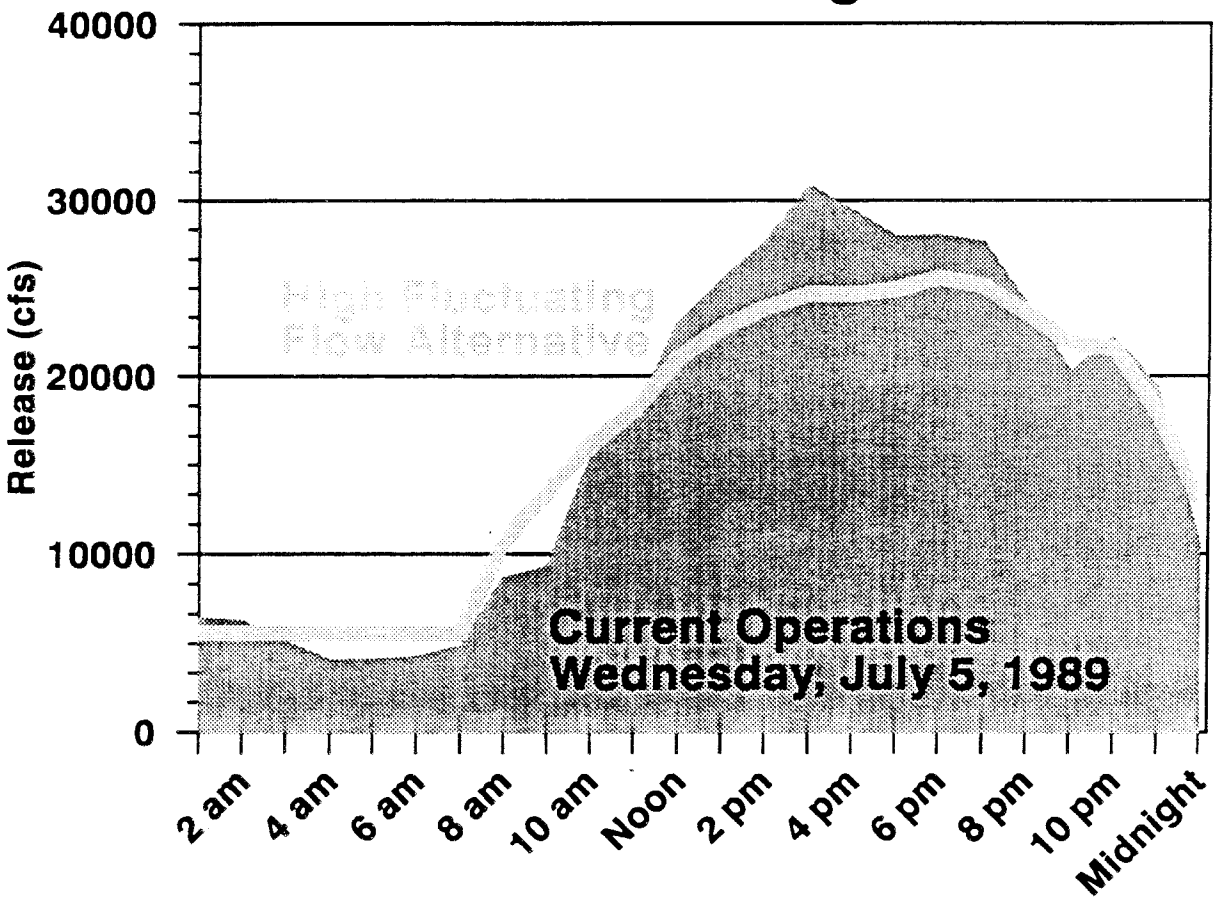
- **Forecast Adjustments.** The volume of water to be released during the remainder of the year would be recomputed monthly based on updated streamflow forecast information (as it is under existing practices), and the rate of release for remaining months would be adjusted accordingly.

- **Avoidance of Spills.** Operational flexibility necessary to avoid spills and maintain conservation storage would <u>not</u> be affected.

- **Ramping Rate.** The ramping rate would follow the power load for increasing flows but be limited to 5,000 cfs/hr or 4,000 cfs/hr for decreasing flows, depending on market conditions.

- **Power Considerations.** Power operations are dependent on monthly water release volumes. Two other factors critical to power operations being able to accommodate changes in dam operations are monthly electrical load and market conditions. Generally, power operations would optimize the water allocation to maximize the ability to generate to meet firm load and to allow greater purchases during off-peak periods, given the release restrictions.

# A day in July under the HIGH FLUCTUATING FLOW ALTERNATIVE might look like...



## NO ACTION ALTERNATIVE

- **Objective.** Existing operational practices would continue under the No Action Alternative. Under the subalternative, current restrictions on using the uprate would be removed.

- **Range of Fluctuating Flows.** The median (equalled or exceeded 50 percent of the time) daily fluctuation in hourly flows for the period 1966-89 ranged from about 11,000 cfs in April to about 16,000 cfs in August. Daily fluctuations greater than 20,000 cfs occurred about 3 percent of the time in April and about 25 percent of the time in August.

- **Maximum Flow.** The maximum flow is determined by the water available in any month. Up to 33,200 cfs is discharged through the powerplant. Flows greater than this capacity are discharged through the outlet works first and subsequently through the spillways, as required. Peak discharges under existing normal operations do not exceed 31,500 cfs. Use of the full powerplant capacity (33,200 cfs) would be studied as a subalternative. The median (equalled or exceeded 50 percent of the time) maximum hourly flow for the period 1966-89 ranged from about 17,000 cfs in October to about 25,000 cfs in August. Peak releases greater than 25,000 cfs occurred about 11 percent of the time in October and about 50 percent of the time in August. The following figure shows current operations for a day in July 1989.

- **Minimum Flow.** Minimum flows allowable have been 1,000 cfs from Labor Day until Easter and 3,000 cfs from Easter until Labor Day (the recreation season). The median (equalled or exceeded 50 percent of the time) minimum hourly flow for the period 1966-89 ranged from about 3,200 cfs in October to about 6,000 cfs in April. Minimum releases less than 2,000 cfs occurred about 30 percent of the time in October and about 9 percent of the time in April.

- **Annual Volume.** The scheduled annual release volume is determined based on considerations for maintaining conservation storage, avoiding spills, balancing of storage between Lakes Powell and Mead, and power needs. This volume is a function of the inflow and remaining space in Lake Powell. From 1966 to 1989, releases have ranged from 8.23 million acre-feet to 20.4 million acre-feet (1984). The minimum release of 8.23 million acre-feet has occurred about 50 percent of the time since 1963.

- **Monthly Volume.** The scheduled monthly release volumes are determined based on considerations for maintaining conservation storage, avoiding spills, and the value of generated electrical energy. The median (equalled or exceeded 50 percent of the time) monthly release for the period 1963-89 ranged from about 550,000 acre-feet in February to about 900,000 acre-feet in August.

- **Daily Volume.** The mean daily release volume is determined principally from the monthly volume. The median (equalled or exceeded 50 percent of the time) daily release volume for the period 1963-89 ranged from about 19,400 acre-feet (9,700 cfs) in March to about 30,000 acre-feet (15,000 cfs) in August.

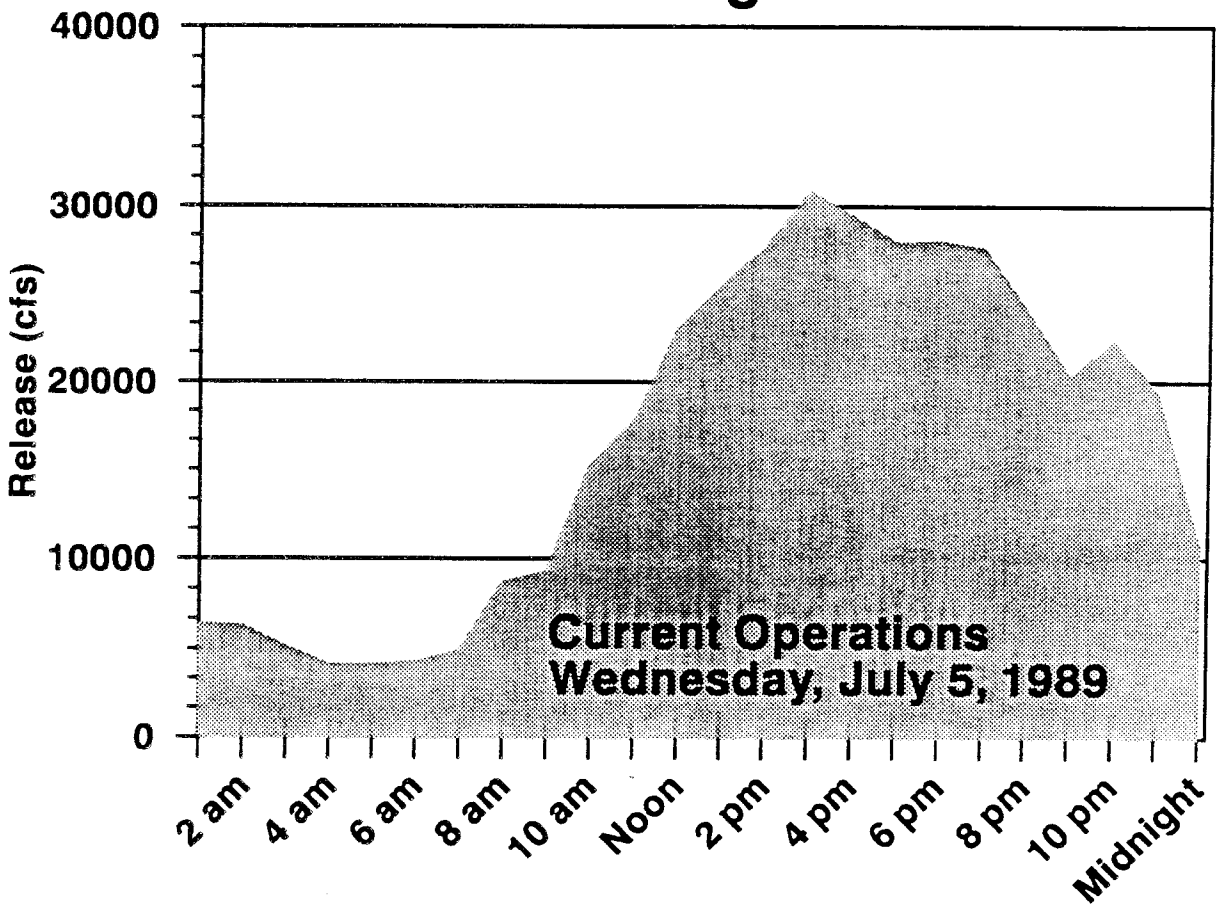
- **Forecast Adjustments.** Each month the volume of water to be released during the remainder of the year is recomputed based on updated streamflow forecast information, and the required release for the remaining months is adjusted accordingly.

- **Avoidance of Spills.** Monthly and annual release volumes are scheduled to avoid spills and to maintain conservation storage in accordance with the "Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs."

- **Ramping Rate.** Ramping rate restrictions are programmed in the power control system and, depending on area control error, are either 17 MW per minute (approximately 430 cfs per minute) or 50 MW per minute (approximately 1,260 cfs/minute). These rates are rarely held over an extended time period, but are equivalent to 25,800 cfs per hour and 75,600 cfs/hour, respectively. Based on the 1980-89 period, ramping rates were below 8,000 cfs/hour 99 percent of the time and below 5,000 cfs 95 percent of the time. The daily ramping rate has historically been less than 8,000 cfs per hour more than 95 percent of the time.

- **Power Considerations.** Glen Canyon power generation is used to meet firm and non-firm load, and to allow off-peak purchases to be made whenever possible. Imposed powerplant capacity is 31,500 cfs.

# A day in July under the CURRENT OPERATIONS might look like...



## ALTERNATIVES CONSIDERED AND ELIMINATED FROM DETAILED STUDY

During the scoping process, including formulation of alternatives, various suggestions and concepts were considered. Some were determined not to be reasonable for detailed analysis, as explained in this section.

### Remove Glen Canyon Dam

**Objective.** A limited number of comments received during the scoping process indicated the desire to remove Glen Canyon Dam from the Colorado River. This concept was not formulated into a detailed alternative.

**Evaluation of Alternative.** Removal of the dam is considered to be unreasonable in view of: (1) the many established beneficial uses that it now serves; (2) the legal framework (or Law of the River) that now exists; (3) the investment that it represents; and (4) the adverse social, economic, and other impacts to the existing human environment in the Colorado River Basin that would result from its removal.

Most importantly, the Glen Canyon Dam EIS Team was directed by the Secretary of the Interior to evaluate alternative operations of Glen Canyon Dam. The concept of removal is an alternative to the dam, and does not address dam operations.

**Conclusions.** This concept is outside the scope of dam operations and therefore violates the Secretary's charge to the EIS Team. As a result, the concept of removal of Glen Canyon Dam has been eliminated from further consideration.

### Run-of-the-River Alternative

**Objective.** Some comments received during the scoping process asked for a water release regime from Glen Canyon Dam that would mimic historic river conditions in the Grand Canyon. The EIS Team responded by forming the Run-of-the-River Alternative. The objective of this alternative was to simulate, as far as possible, the downstream conditions that existed before Glen Canyon Dam. The simulation would be achieved through operational changes at Glen Canyon Dam and by adding structural mechanisms.

**Description of Alternative.** The Run-of-the-River Alternative addressed annual streamflow patterns, sediment transport, and water temperatures. The goal of this alternative was to approximate the historic pattern of high spring flows and low fall/winter flows by matching releases from the dam with inflows into Lake Powell. Spring releases would be limited to 45,000 to 50,000 cfs unless the reservoir was full; then releases would equal inflow. Under these operating principles and based on predam inflows, flows in May could exceed 45,000 cfs about 40 percent of the time, and June flows could equal or exceed 45,000 cfs about 60 percent of the time. Minimum flows of about 1,000 cfs would occur during winter and late summer.

The frequency of high flows needed to simulate predam conditions would scour most of the sediment in the Grand Canyon. Tributaries below Glen Canyon Dam cannot supply

large amounts of sediment on an annual basis, so the sediment would not be replaced naturally. Scouring sediment from the Grand Canyon would damage environmental, recreational, and cultural resources in the canyon. Sediment losses are now reduced by regulating the frequency of high-flow releases from Glen Canyon Dam.

For these reasons, the Run-of-the-River Alternative would require massive sediment augmentation (up to 10 million tons annually) in order to replenish sediments transported out of the system. Potential sediment delivery systems considered included barges, trucks, and a sediment slurry pipeline. Sediment would be dredged from a remote source, and then transported and deposited in the Colorado River on a continual basis. The river would then carry the sediment downstream for deposit in main channel pools.

The areas of Lake Powell considered as possible sources of sediment were the upstream delta along the mainstem (Cataract Canyon), the San Juan River, and Dirty Devil River. Any sediment source would have to be renewable in order to sustain the beaches in the Grand Canyon indefinitely under the suggested water-release regime.

In order to more closely approximate predam seasonal patterns, some type of temperature modification was needed in the Run-of-the-River Alternative. To increase river water temperature, multilevel intake structures would be placed on the dam penstocks to draw warmer water from near the reservoir surface for release downstream. This approach would raise downstream water temperatures 5 to 18 °F above current conditions.

**Evaluation of Alternative.** Evaluation of the Run-of-the-River Alternative focused primarily on flows/sediments, environmental concerns, and compact and treaty requirements.

*Flows/Sediments.* Sediment augmentation is required to maintain a sediment balance in the system when high releases are frequent. Without sediment augmentation, the Run-of-the-River Alternative would eventually erode most of the sediment from Grand Canyon—damaging the canyon's environmental, recreational, and cultural resources.

The cost of building a slurry pipeline is estimated at $400,000 per mile. For a completed pipeline to the river deltas of the San Juan, Dirty Devil, or the mainstem (Cataract Canyon), costs are estimated at $50, $80, and $85 million, respectively. Operational costs could be $10 to $20 million per year. Other means of sediment transport (barging or trucking) would be more expensive than a slurry pipeline.

A slurry pipeline would likely take at least 15 to 20 years to implement after a Record of Decision. This timeframe includes appropriate research and data collection, NEPA compliance, design, Federal permitting, congressional authorization, land purchase/easements, implementation of mitigation procedures, construction, and the determination and implementation of interim operations for Glen Canyon Dam.

*Environmental Concerns.* Any overland route for sediment transport to the Colorado River below Glen Canyon Dam would cross more than 100 miles of high-desert canyon 9landscape to reach the nearest renewable source of sediment. Construction would cause adverse environmental impacts to fragile resources. Cultural and archeological impacts on tribal lands would likely be significant and, in the case of sacred sites, could not be mitigated.

Low flows from this alternative during the winter spawning season would directly impact rainbow trout, and extended low flows at any time would impact the *Cladophora-Gammarus* segment of the aquatic food chain throughout Grand Canyon.

The high spring flows would scour most of the sand deposits from the river above Lees Ferry. This would occur because slurry sediment would be delivered below the ferry, and none of the tributaries above the ferry can deliver enough sediment to offset the losses of sediment caused by increases in river flow.

Addition of up to 10 million tons of new sediment annually to the river below Glen Canyon Dam would alter the aquatic ecosystem. Increased turbidity would limit light penetration and affect the algae *Cladophora*, and thus the remainder of the food chain dependent on it. One of the most important segments that would be affected is *Cladophora-Gammarus*, which is vital in the food chain for rainbow trout and bald eagles. Significant changes in turbidity could also affect aquatic insects fed upon by swallows and bats which are, in turn, fed upon by peregrine falcons and other species.

Important unanswered questions exist concerning the types and amounts of contaminants that may be found in some of the sediment sources identified above and their effects on resources if added to the aquatic system below Glen Canyon Dam.

Lastly, modification of water temperature in the Colorado River below Glen Canyon Dam presents both opportunities for enhanced management of some resources and risks associated with unknown responses. Increased water temperature in the river channel may benefit humpback chub and other native fishes, but may also improve habitat conditions for competing exotic species and permit an invasion of striped bass from Lake Mead. The current water temperature is below the optimum for rainbow trout growth, but it is unknown how *Cladophora* and *Gammarus*—upon which trout are now dependent—would respond to increased temperatures.

*Compact and Treaty Requirements.* During extended drought cycles in the Upper Basin, releases from Glen Canyon Dam under this alternative would not be able to meet the requirements of the Colorado River Compact and the treaty with Mexico. Either the Upper Basin States would have to release more water from upstream reservoirs or the compact and treaty would have to be renegotiated.

Under the Run-of-the-River Alternative, releases from the dam could only match high spring inflows when Lake Powell was full and the spillways could be used. Because of the way the dam is designed, the spillways cannot be used unless the reservoir is full. Without using the spillways, releases cannot exceed approximately 45,000 cfs. Inflows to Lake Powell in June typically exceed 45,000 cfs, and the amount in excess of 45,000 cfs would have to be stored in the reservoir until it filled. Lake Powell could be expected to fill and spill about once every four years under this alternative.

**Conclusions.** The Run-of-the-River Alternative attempted to define conditions similar to those that existed in the Colorado River before Glen Canyon Dam and to identify operational and structural mechanisms that could be used to attain these conditions.

Analyses indicated that, under the alternative, the river would be converted into a system very different from existing conditions and operations. System changes would create

significant impacts to important resources associated with the aquatic food chain, most notedly *Cladophora*, *Gammarus*, aquatic insects, trout, swallows, bats, bald eagles, and peregrine falcons. During extended drought periods, the Upper Basin States would have to release additional water from upper basin reservoirs to satisfy the requirements of the Colorado River Compact and the treaty with Mexico.

Most of these impacts would be associated with the massive addition of sediment needed to prevent the net loss of sediment deposits during high releases. Any sediment augmentation approach would cause environmental damage along any transport route selected, would require perhaps more than 20 years to implement, and would be very costly both for construction and operation.

Without sediment augmentation, the volumes of clear-water releases defined in this alternative would eventually eliminate most sediment deposits along the Colorado River in Grand Canyon. This includes beaches and their recreational opportunities, cultural resources, backwaters, wetlands, and riparian vegetation. Mitigating these impacts by reducing seasonally high flows creates a flow regime incorporated into the Seasonally Adjusted Steady Flow Alternative.

In conclusion, the desire to return river flows to a more historic (predam) pattern is recognized. A return to a seasonal streamflow pattern emulating the magnitude of historic spring flows would, however, be very destructive to remaining downstream resources unless a large-scale, long-term sediment augmentation program was added. Such a program would be expensive in terms of environmental damage and construction and operation costs.

Sediment resources within Grand Canyon are believed to be best preserved by reducing the frequency of high-flow releases and thus eliminating the need for massive sediment augmentation from sources outside the Grand Canyon. The Run-of-the-River Alternative has, therefore, been determined to be unreasonable and has been eliminated from further consideration.

### Historic Pattern Alternative

**Objective.** Comments received during the scoping process indicated the desire of some respondents to alter dam releases to return to predam flow patterns. The Historic Pattern Alternative seeks to follow predam water flow patterns more closely while still managing flows within current powerplant operational capacity.

**Description of Alternative.** This alternative was a modification of the Run-of-the-River Alternative. Flows would be held steady each month while following a seasonal pattern of higher spring/summer and lower fall/winter flows. Maximum flows would be limited to 33,200 cfs and minimum flows would be determined by the forecasted annual release remaining after high spring/summer flows were allocated.

The Historic Pattern Alternative included a sediment slurry pipeline and multilevel intake structures for the reasons discussed under the Run-of-the-River Alternative.

**Evaluation of Alternative.** Although flows under the Historic Pattern Alternative would be of less magnitude and perhaps of shorter duration than under the Run-of-the-River Alternative, sediment augmentation would still be required to prevent long-term adverse impacts to downstream resources. Without sediment augmentation, the sediment resources along the Colorado River would be more subject to erosion under the Historic Pattern Alternative than under any of the steady or fluctuating flow alternatives, including the No Action Alternative.

The Historic Pattern Alternative is not expected to conflict with the Colorado River Compact or the treaty with Mexico.

**Conclusions.** The Historic Pattern Alternative was eliminated from detailed study for most of the reasons given for the Run-of-the-River Alternative. Specifically, sediment augmentation would cause adverse impacts to important components of the aquatic ecosystem below Lees Ferry, and high and low flows might impact resources above Lees Ferry.

Without sediment augmentation, the flows under this alternative would cause more erosion to sediment deposits below Glen Canyon Dam than other steady or fluctuating flow alternatives, including current operations. Mitigating these impacts by reducing seasonally high flows creates a flow regime incorporated into the Seasonally Adjusted Steady Flow Alternative. For these reasons, the Historic Pattern Alternative has been eliminated from further consideration.

### Maximum Fluctuating Flow Alternative

**Objective.** The EIS Team responded to scoping comments requesting full use of Glen Canyon Dam powerplant's generating capacity by developing the Maximum Fluctuating Flow Alternative. The objective of this alternative was to initiate operational changes to fully utilize powerplant generating capacity (flows of 33,200 cfs) while reducing, to the extent possible, existing adverse impacts to downstream resources.

**Description of Alternative.** This alternative would be similar to existing operations with increases in maximum flows to 33,200 cfs and establishment of minimum flows at a uniform 1,000 cfs. Annual and monthly releases would be based on the following factors: meeting water deliveries to the Lower Basin States, maintaining conservation storage in Lake Powell, avoiding spills, balancing storage between Lake Powell and Lake Mead, and power demand. Daily releases would be patterned to meet power demand, as determined by the monthly release volume. Ramp rates would be unconstrained except for physical limitations of the powerplant.

An increase in the frequency and magnitude of daily fluctuations would cause additional impacts to downstream resources at levels above those documented for current operations (i.e., the No Action Alternative at 33,200 cfs). To reduce new and existing impacts, a reregulation dam would be constructed approximately one mile upstream of the gauge at Lees Ferry to provide near constant steady flows downstream of the reregulation dam.

Flows below the reregulation dam would follow a pattern of steady flows adjusted to accommodate required monthly water releases. Median monthly volumes historically have

ranged from 550,000 acre-feet (about 10,000 cfs) to 900,000 acre-feet (15,000 cfs). Minimum steady flows would be about 8,000 cfs and maximums would be dictated by the monthly volume to be released. Downstream of the reregulation dam, small daily changes in flow volume would occur, but changes in river elevation would be nearly imperceptible. There potentially could be changes between weekdays and weekend days because the average daily release may be lower on a weekend day than on a weekday; however, the transition between flows would be gradual. Effects of ramping would be virtually unnoticeable below the reregulation dam.

The river between Glen Canyon Dam and the reregulation dam (Lees Ferry reach) would be converted to a fluctuating reservoir storing water during part of the day for release later in the day. Minimum river elevation at the upstream face of the reregulating dam would increase 4 feet, and the range of fluctuation would increase up to 17 feet daily. The range of fluctuation would decrease progressively upstream of the reregulation dam. River elevation would peak between 4 and 8 p.m. and fall to a minimum between 4 and 8 a.m. This fluctuating reservoir would act as the damper to accept the fluctuating releases of Glen Canyon Dam and convert them to near steady releases below the reregulation dam.

**Evaluation of Alternative.** The Maximum Fluctuating Flow Alternative would meet its primary objective of providing complete flexibility in power operations at Glen Canyon Dam while providing a mechanism for protection of physical and biological resources downstream from Lees Ferry (260 miles). However, the river reach between Glen Canyon Dam and the reregulation dam (15 miles) would be significantly altered by increased fluctuations above the reregulation dam.

*Flows/Sediments Resources.* Steady flows below a reregulation dam would virtually eliminate rapid changes in flows, and would maintain flows below critical sediment transport levels except during flood operations. Under these conditions, natural input of sediments from tributaries (Paria and Little Colorado Rivers) could maintain a sediment balance in the river corridor below the reregulation dam. Steady releases would reduce the erosion of materials from already established beaches.

Fluctuations in flow above a reregulation dam would be considerably higher than under current operations. Sediments in the Lees Ferry reach exposed to these higher releases, would continue to be lost. Further, because the range of fluctuation would be shifted as much as 4 feet higher in elevation, beach deposits that have been above current normal operational ranges would be subject to fluctuations and loss. Because this reach lacks a source of sediment input, these operations would eventually eliminate much of the sand and fine grained sediment from beaches in the Lees Ferry reach.

*Riparian and Terrestrial Resources.* Stabilized flows downstream of a reregulation dam would promote further development of riparian resources on stabilized beach deposits in Grand Canyon. Terrestrial wildlife linked to riparian resources would benefit from the stabilized riparian corridor.

The Arizona Game and Fish Department would categorize the riparian habitat found in the reach between the dam and Lees Ferry as Resource Category I habitat, and would recommend that all potential losses of existing habitat values be prevented. Riparian habitat associated with perennial streams in Arizona is considered unique and irreplaceable on a statewide basis.

The loss of beach deposits in the reach above the reregulation dam would result in direct loss of riparian resources. A segment near the reregulation dam would be immediately inundated, and virtually all riparian resources would be eliminated as beach deposits from this reach erode. Because the endangered peregrine falcon feeds on prey linked to riparian communities, elimination of riparian resources above the reregulation dam would impact peregrine falcons using Glen Canyon.

*Aquatic Resources.* The placement of the reregulation dam would not directly disturb habitat utilized by the endangered humpback chub. Reregulated flow to the river reaches below the Little Colorado River would potentially stabilize backwaters and promote differential warming that would provide rearing habitat for larval or juvenile chub. The river channel would remain cold, thus limiting the movement of larval humpback chub out of the Little Colorado River. Stabilization of flows would not guarantee that backwaters would be maintained through time. As backwaters developed into riparian areas over time, they would eventually lose their value as fish rearing habitat. No additional spawning habitat for chub would be provided nor would stabilization encourage the development of secondary spawning populations.

The aquatic system above the reregulation dam would be altered. Accelerated beach erosion, caused by increased fluctuations, combined with lake-like conditions lower in the reach above the reregulation dam would favor planktonic algal forms, which could result in a decrease in water clarity. Changes in water clarity combined with weekend minimum stages could reduce the zone occupied by *Cladophora*. Reduced *Cladophora*, and/or reductions in its transport out of the reregulating reservoir could result in restructuring energy flow throughout the river in Grand Canyon.

Restructuring of the food chain above and below the reregulation dam would effect the existing trout fishery. The resource would change from a "stream" to a "lake" fishery with very different management needs and expectations. Natural reproduction would be reduced. Impacts to *Cladophora* and the algal/invertebrate community associated with *Cladophora* would reduce the probability of maintaining a blue ribbon trout fishery.

*Cultural and Historic Resources.* Sand and sediment deposits cover and protect many important cultural and religious sites along the river corridor. Stabilized flows below the reregulation dam would slow the erosion processes that are exposing and damaging these sites throughout the Grand Canyon.

More than 40 cultural and historic sites have been documented in the Lees Ferry reach. In addition, two locations currently under evaluation possibly are Hopi spiritual sites. Greater fluctuations would increase erosion that is currently impacting sites. Impacts to many historic and cultural sites could be mitigated through excavation, but others could not be moved because of their delicate nature. If these sites are determined to be sacred to native Americans, then by their nature they cannot be moved, transferred, or excavated.

The reregulation dam would be built within the historic district of Glen Canyon National Recreation Area. Increased beach erosion and the inundation of additional areas of the Lees Ferry reach would impact the cultural heritage associated with the last remaining miles of Glen Canyon. This registered historic area also contains a registered historic site, the Charles H. Spencer Steamboat (located downstream from the potential damsite). Activities that may impact sites listed on the National Historic Register, especially those

that would alter the setting that justified registration, generally are not allowed. Construction would require consultation and coordination with state (State Historic Preservation Officer) and national (Advisory Council on Historic Preservation) officials.

*Recreation.* White-water rafting would not be inhibited by the steady flows below a reregulation dam; steady flows above 8,000 cfs could be considered desirable conditions.

Recreation above a reregulation dam could, however, change dramatically from current conditions. The Lees Ferry reach is typically used by day-use rafters and sport fishermen. Access to the reach across the historic area of Glen Canyon National Recreation Area is, as yet, an unresolved issue. The nature of access and the recreational fishery would undoubtedly change.

Safety would be a major concern for those using the reregulating reservoir. A boat ramp would provide access upstream of the reregulation dam. Sustained high flows above powerplant capacity would overtop the reregulation dam. Boat launching or operation near the reregulation dam under high flow conditions would be dangerous. Sustained high releases would result in closure of the area, likely preventing recreational use of this segment of the Glen Canyon National Recreation Area for extended periods of time. Such closures during the high flows of 1984 and 1985 would have exceeded 24 months.

*Economics.* Construction cost of a reregulating dam is estimated at $60 to $110 million. A reregulation dam would permit operation of the powerplant at maximum capacity whenever enough water was available (Lake Powell elevation greater than 3683 ft.) and electrical demand was high. Estimates show that, under these criteria, the powerplant would operate at maximum capacity about 25 days per year (7 percent of the time) for less than 4 hours at a time. It is very unlikely that the monetary benefits of this additional power and energy generated—as compared to current operations or the No Action Alternative—would be equal to the cost of the reregulation dam.

*Public Acceptance.* Construction would require specific congressional authorization, and would be guided by the Federal Government's "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" that govern all implementation studies. These Principles and Guidelines apply the four tests of completeness, effectiveness, efficiency, and acceptability to all project alternatives considered as reasonable for action. Although some segments of the public would find a reregulation dam acceptable, a wide and diverse group of publics have expressed strong opposition to placing a dam in the last remaining reach of the Colorado River in Glen Canyon.

*Administrative Clearance.* A reregulation dam would take at least 5 to 15 years to construct after the Record of Decision. This estimate includes such activities as research and data collection, NEPA compliance, design, Federal permitting, consultation with the State Historic Preservation Officer and the National Advisory Council on Historic Preservation, excavation of cultural sites, consultation under the Endangered Species Act, congressional authorization, implementation of mitigation procedures, determination and implementation of interim operations for Glen Canyon Dam, and construction. Construction impacts would be irreversible.

Construction projects that place fill in waters of the United States are governed under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. Normally, the process is administered by the U.S. Army Corps of Engineers following guidelines from the U.S. Environmental Protection Agency (EPA). Because the dam would require congressional authorization, the normal permitting process under the Clean Water Act could potentially be bypassed [Section 404 subsection (r)], but EPA guidelines would apply to project NEPA compliance. Those guidelines [Section 404(b)(1)] require that alternatives must be weighed for construction in waters of the United States. These guidelines also require selection of the "least damaging practicable alternative" to the aquatic ecosystem.

The Glen Canyon Dam EIS would have to disclose the impacts associated with constructing a reregulation dam, and would be required to demonstrate that it would be the "least damaging (to the aquatic ecosystem) practicable alternative." Such a demonstration would be very difficult.

**Conclusions.** The Maximum Fluctuating Flow Alternative attempted to define water releases that would maximize the power generating capacity of Glen Canyon Dam and identified structural mechanisms that would provide protection to downstream resources. Analyses indicated that, while most downstream resources would experience improved conditions over the No Action Alternative, resources in the Lees Ferry reach would experience increased frequency and magnitude of daily river fluctuations, which could have negative effects.

Resources in the Lees Ferry reach that would experience significant impacts include beaches and other sediment deposits, riparian vegetation and associated terrestrial wildlife, *Cladophora* and the algal and invertebrate communities associated with it, a regionally significant trout fishery, recreation potential in a National Recreation Area, native American cultural and sacred sites, and archeological and National Historic areas/sites. Impacts to the *Cladophora*-based aquatic food chain could affect energy flow throughout the Grand Canyon.

Most of these impacts would result from increased frequency and magnitude of fluctuations behind a reregulating dam constructed to protect downstream resources from those same fluctuations. A reregulating dam would require $60 to $110 million to construct and 5 to 15 years to implement without opposition. Without a reregulation dam, many of the impacts predicted for the Lees Ferry reach would occur downstream in Grand Canyon.

Impacts to the Lees Ferry reach could be mitigated by reducing the frequency and magnitude of daily river fluctuations. Without maximum fluctuations there would be no need for a reregulation dam. Reduced fluctuations and elimination of the reregulation dam create conditions identical to those evaluated under other fluctuating flow alternatives including No Action. The No Action Alternative actually evaluates conditions under a range of flows from 1,000 cfs to 33,200 cfs.

In conclusion, predicted impacts to resources, acceptability problems under the Principles and Guidelines, and the scrutiny of Section 404 of the Clean Water Act combine to render this alternative unreasonable. The Maximum Fluctuating Flow Alternative has been eliminated from further consideration.

### Reregulation Dam as a Separate Feature

A reregulation dam could be considered as a mechanism for providing steady flows downstream, and consequently be economically justified on the basis of the power values preserved when the various steady flow alternatives are compared to the No Action Alternative. Such power values are significant and could be greater than the cost of a reregulation dam.

However, adverse impacts to the Lees Ferry reach of the Colorado River, poor acceptability, authorization problems, and Clean Water Act compliance difficulty would be the same as described under the Maximum Fluctuating Flow Alternative. Therefore, it was concluded that a reregulation dam should not be analyzed further either as a part of a maximum power generation alternative or as part of other fluctuating flow alternatives.

### Move Hydropower Peaking from Glen Canyon Dam to Hoover Dam

Both Glen Canyon and Hoover are already operated as hydroelectric power peaking plants, and there appears to be no excess capacity or energy available at Hoover to substitute for reduced peaking at Glen Canyon. All of the capacity and energy at Hoover is allocated with existing contracts.

It has been suggested that Hoover could be modified with more units to increase capacity and supply the peaking that now occurs at Glen Canyon. There are two factors that interfere with this suggestion:

1. Hoover modification is already being considered by the Arizona Power Authority and the Colorado River Commission of Nevada to augment their peaking needs, and therefore power produced at Hoover would not be available for use in the area served by Glen Canyon power.

2. If additional units were installed at Hoover, the necessary additional water in Lake Mead would not be available to fully satisfy peaking requirements.

It may be possible in the future to apply additional computer technology on a regional (or system) basis to refine and enhance the efficiency of the network of various powerplants, including Glen Canyon and Hoover. This could facilitate some peaking and spinning reserve adjustments between the two projects. However, institutional concerns, prolonged negotiations, and other necessary arrangements would be very complex and likely extend well beyond the scope and timeframe covered by the Glen Canyon Dam EIS.